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ORIGINAL ARTICLE

Present and future environmental impacts on the coastal zone of Berau (East Kalimantan, Indonesia), a deductive scenario analysis

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Abstract Using the drivers–pressures–state–impact–responses (DPSIR) analytical framework, local stakeholder respondents and experts were interviewed to construct and prioritize a causality network that links ecosystem state of the coastal waters of Berau (East Kalimantan, Indonesia) with societal drivers of change. Particularly on the perceived top priority drivers and pressures, consensus among respondents was considerable. The constructed network was found to be consistent with literature findings from elsewhere in SE Asia. This causality network was then confronted with a local articulation of the SRES scenarios (IPCCs Special Report on Emissions Scenarios: A1, A2, B1, B2), and four plausible trajectories of future change were deduced over a period of 20 years, until 2030. Our scenario articulations differed greatly in the projected immigration influx into the region, in local economic growth and in institutional strength of governance. Under business-as-usual conditions, it is foreseen that fisheries will continue to overexploit the resource, and inland and mangrove deforestation, as well as sediment and sewage loading of the coastal waters, will increase, leading to declines in coral and seagrass extent and depleted fisheries. Scenarios with continued immigration (~A1, A2) will probably aggravate this pattern, whereas those with reduced immigration (~B1, B2) would appear to lead to considerable improvements in the state of the coastal waters of Berau.

Keywords DPSIR framing · Land-coast impacts · Deforestation · Overfishing · Transmigration · Global change · Ecosystem services

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Introduction

The Berau district in East Kalimantan, Indonesia, has witnessed a considerable increase in human population since its designation as destination for the Indonesian transmigration programme in the 1980s (Huttche 2002). Registered citizens have increased from 56,000 to 164,000 between 1988 and 2007 (Obidzinski and Barr 2003; Badan Pusat Statistik Kabupaten Berau 2008). These people have mainly found a livelihood in the exploitation or extraction of natural resources (ESG International 2002). More than half of the workforce in the area is engaged in agriculture (which includes forestry, Obidzinski and Barr 2003), and agriculture and mining contribute, respectively, 26 and 35% to the GRDP (ESG International 2002). These human activities are thought to have adverse environmental impacts. Notably, forest clearance, mining and overfishing are considered to affect the coastal zone of Berau (MacKinnon et al. 1997; ESG International 2002; Huttche 2002). At the same time, Berau is located in one of the world's major biodiversity hot spots (MacKinnon et al. 1997; Tomascik et al. 1997), and environmental degradation may have profound impacts on this biodiversity. For example, Berau's lowland forests are

home to a population of Orang Utan and many otherwise rare mammals, and the coastal waters probably harbour the highest diversity in the Coral Triangle, the centre of marine species richness and a top priority area for marine conservation (Veron 1986; Tomascik et al. 1997; Renema 2006; Hoeksema 2007; De Voogd et al. 2009).

In this scoping study, we attempt to assess the relative importance of a range of environmental impacts in the coastal zone of Berau, chart their relations with possible driving forces and elaborate possible future trends. We applied the drivers–pressures–state (change)–(societal) impact–response (DPSIR) analytical framework (e.g. Smeets and Weterings 1999; Gabrielsen and Bosch 2003; Langmead et al. 2009; Udo de Haes and Heijungs 2009) to qualitatively identify causal relations. We combine this with a regional articulation of global socio-economic scenarios, those of the IPCC SRES working group (SRES = Special Report on Emissions Scenarios, Nakicenovic and Swart 2000; Greeuw et al. 2000; Lorenzoni et al. 2000; Berkhout et al. 2002; Busch 2006; EEA 2009).

Our specific research questions are as follows: (1) What are the plausible major causal pathways linking global and regional drivers to pressures and subsequent state change in the ecosystems of the coastal zone of Berau?; (2) What would be the possible effect of four trajectories of future development based on existing SRES scenarios?

Approach

First, a qualitative DPSIR network of causality was drafted by the authors, as in Langmead et al. (2009). Environmental change due to pressures is interpreted here as being contained in 'State Change', whereas 'Impact' is interpreted as the impact that this environmental change has on society (cf Langmead et al. 2009; Udo de Haes and Heijungs 2009). This draft DPSIR model was constructed from literature (notably Tomascik and Mah 1994; Oosternan 1999; ESG International 2002; Huttche 2002; Ismuranty et al. 2004; Obidzinski and Barr 2003; Keulartz and Zwart 2004; Wiryawan et al. 2005) and our local and regional field expertise (Terrados et al. 1998; Wesseling et al. 2001; Kamp-Nielsen et al. 2002; Vermaat et al. 2005; Becking and Lim 2009; De Voogd et al. 2009). Our draft DPSIR model was then confronted with the critical views of experts and representatives of local stakeholder groups ("Appendix") and subsequently revised. Using this verified DPSIR model, the four SRES scenarios were deductively downscaled (as in for example Döll and Vassolo 2004, see below), articulated for this specific coastal zone and also reviewed with our respondents. A limited set of aggregate indicators was chosen to reflect the state of the coastal ecosystems, as a compromise between relevance, comprehensiveness and stakeholder understanding (cf English et al. 1994; Langmead et al. 2009): transparency of the water, vitality and cover of corals, cover and extent of seagrass and mangroves, and stocks of commercial fish and shrimp as well as sea turtles.

Stakeholder categories (Grimble and Wellard 1997) were adopted from the in-depth study of local stakeholder relations by Keulartz and Zwart (2004) on the Derawan archipelago, situated along the northern coast of the Berau archipelago. Keulartz and Zwart (2004) used a 3×3 matrix to categorize stakeholders based on their role in management (civic, governance and commercial) and their operational scale (local/regional, national and supranational). The representatives of commercial entrepreneurs those we approached chose not to participate, resulting in 11 out of 18 respondents. This partial response may have affected our prioritization and limits the usefulness of comparing respondent categories. Another consequence is that most respondents were comparatively well educated.

Table 1 Long-list of different potentially important drivers, pressures and state changes that have been presented to stakeholder representatives and experts

DPSIR entry	Alternative issues/entities
Drivers	Human population growth, human migration, national decentralization policy, weak enforcement and legislation, poverty, coastal tourism, coastal infrastructure development, fisheries, mariculture, navigation, coal mining, demand for paper pulp, construction- and fuelwood, climate change
Pressures	Overfishing (including blast and cyanide practices and illegal gears), flooding, siltation, industrial and domestic sewage discharge, eutrophication, mangrove conversion and overexploitation, rising sea surface temperature, sea level rise, declining freshwater resources, deforestation (to meet demands for wood and agricultural land), urban expansion
(Coastal ecosystem) state changes	Declining fish and shrimp stocks, beach erosion, oral mortality, coral bleaching, outbreak crown-of-thorns starfish, increased turbidity, algal blooms, seagrass decline, declining sea turtle stocks, declining sea mammals and sea birds, establishment of invasive species, toxic fish, declining mangrove area
(Societal) impacts	Declining fisheries yields and income, human health reduction, social tension, less revenues from tourism, deterioration of coastal defences, loss of mangrove services
(Societal) responses	Policy development/adjustment targeting national or regional drivers and pressures related to urban spread, land use change and marine exploitation, stronger enforcement of legislation, establishment Berau Marine Conservation area

Table 2 Local articulation of four scenarios for the coastal zone of the Berau district, East Kalimantan, Indonesia, over the coming 20 year, which is up to 2030

Articulated scenario descriptor (SRES label)	Brief narrative
Business as usual	Government focus is on developing fisheries and coal mine sectors. Migration from Java continues, and the labour force is absorbed in these two sectors. Forest is decimated and the pulp industry experiences a shortage in raw resources; reforestation lags behind. Urban and industrial demands for space continue to increase and are mainly resolved along the coast; hence, mangroves are cleared and the delta continues to carry a heavy sediment load towards the sea. Coastal tourism increases
Peopling the world; high human migration, low economic growth (~A2)	Increased migration influx into the regency is not met with sufficient labour, which leads to substantial unemployment. National policy is implemented locally, but public governance[a] is weak. Deforestation doubles and the forest resource is rapidly depleted. Squatter subsistence farming expands on poor, unsuitable soils with little profit and erosion and siltation are enhanced. Also fisheries efforts increase, though catch per unit effort drops. Tourism is in the hands of a few private companies and expands, though only on the national market, whereas biodiversity declines
Industrialization; high human migration, high economic growth (~A1)	Immigration influx continues to increase, whereas governance deploys its strength to enhance economic development. National governance dominates, policy is driven by international trade blocks, and environmental policy serves to support or correct the market. Worldwide, carbon trading is well established, and Berau's inland forests are set aside for this purpose, since the REDD[b] mechanism is well established. As a consequence, the paper and pulp industry declines, and tourism is directed towards these forests. Fisheries, mining and industries develop, the latter inshore, and leading to mangrove loss. Sediment loads from inland slopes are reduced, but domestic and industrial sewage continues to affect coastal water quality
Increasing GDP; low human migration, high economic growth (~B1)	Government power is regionalized, and the regency government is effectively empowered. All economic sectors expand in well-regulated markets, and tax revenues allow the regency's government to implement and enforce its policy well. Technological innovation, education of the workforce and community involvement are considered important, and renewable energy is favoured. Berau's society develops towards more sustainable lifestyles. Yet, forest cover decline cannot be countered fully and replanting schemes pick up late. Mangrove cover declines and coastal siltation continues, whilst international tourism expands
Local responsibility; low human migration, low economic growth (~B2)	Policy of the regency focuses on local sustainability and domestic demands including local resource exploitation, social equity, environmental protection and reduced immigration. Strong governance at regency level allows policy enforcement. Mining, forest use, fisheries and local industries become largely sustainable with a focus on tree replanting and mariculture schemes. Mangroves do not decline and coastal habitats recover strongly. Tourism declines and GDP grows less than in other scenarios

Although the primary dimensions separating the scenarios were chosen to be specific to the Berau situation and do not fully correspond to those of SRES, an indicative SRES label has been added for comparative reasons based on Busch (2006)

[a] Governance is perceived here following the World Bank (1991) definition: the use of policy outcomes and institutions to manage society's problems and affairs

[b] REDD, Reducing Emissions from Deforestation and Forest Degradation in Developing Countries, is a mechanism under development that offers financial compensation for carbon sequestration in re-afforested tropical woodland (cf. MEA, Millennium Ecosystem Assessment 2005 and http://www.un-redd.org/)

About half is stakeholder representative, and three quarter has the Indonesian nationality ("Appendix"). Questions posed (for full questionnaire text, see Estradivari 2008) were open-ended, semi-closed as well as multiple choice. Respondents were asked to rank different drivers, pressures and state (change) indicators from a purposefully extensive long-list (Table 1). Where prioritization was needed, statements on effects or importance had to be scored between 1 (bad or insignificant) and 10 (good or highly important). Only high-priority entities (score > 6) and relations with majority consensus among informants were included in the final DPSIR scheme.

Since their use in public policy and private business in the 1960s (Ringland 2002), scenarios have become a well-established tool to explore how the world would look somewhere in the distant or near future. Scenarios have been defined as coherent, internally consistent and plausible descriptions of possible future states of the world (Parry 2000; Berkhout et al. 2002; Busch 2006). Scenario descriptions are often qualitative and broad-brush 'narratives', contrasting but broad, over-our-head trajectories of world development. The IPPC (Carter et al. 2001; IPCC 2007) and also the Millennium Ecosystem Assessment (MEA, Millennium Ecosystem Assessment 2005) have used a common set of four scenarios, the SRES scenarios (Nakicenovic and Swart 2000; Lorenzoni et al. 2000). These have become a successful, well-cited (cf Busch 2006; Hettelingh et al. 2009) attempt to describe strongly contrasting potential directions of world development. Downscaling of scenarios may detail aspects of the

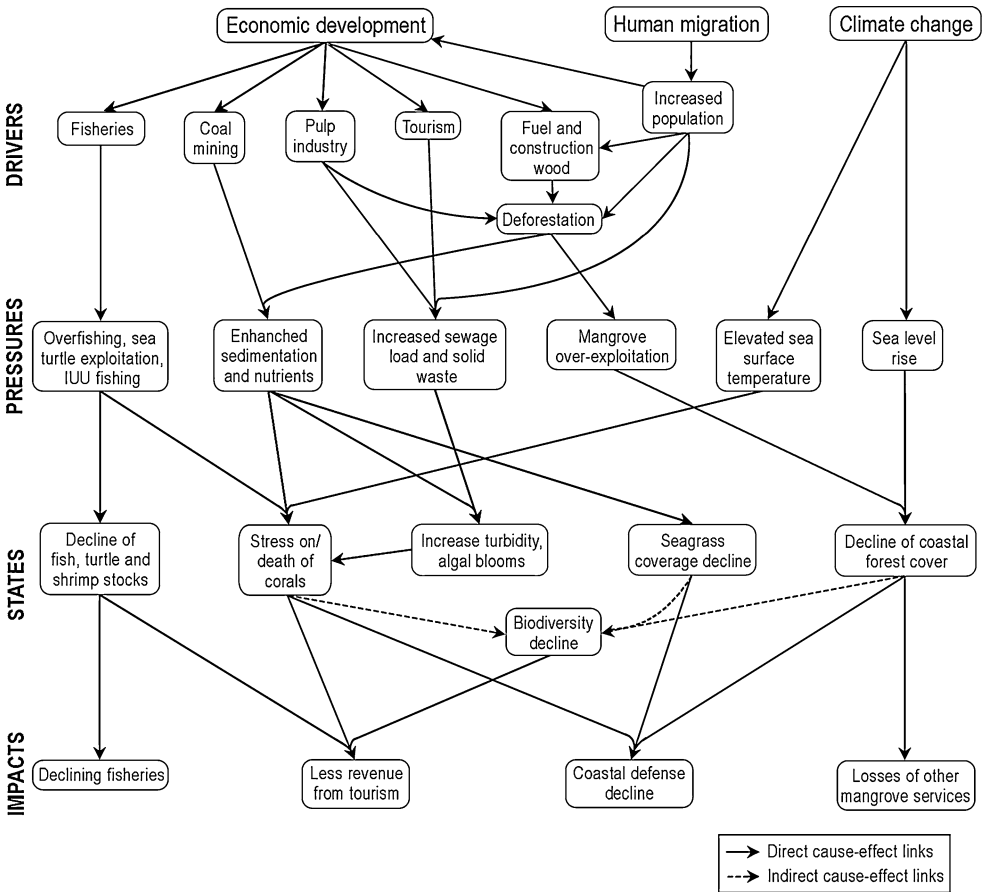

Fig. 1 DPSI model depicting causality links underlying environmental change in Berau's coastal zone after verification with stakeholders and experts. Drivers, pressures, state change and societal impacts are depicted. Possible societal responses (the R in DPSIR) are left out but could be taken at the level of drivers and pressures

distribution of wealth (Van Vuuren et al. 2007), the intensity and planning of land use and natural resource exploitation (Verburg et al. 2006), types and distribution of recreation, the planning and regulation of urban sprawl (Gaffin et al. 2004), adopted lifestyles by the population at large including health and demographic aspects (Döll and Vassolo 2004), as well as governance styles and institutional strength (Busch 2006).

Regional, downscaled scenario articulation was made with a 20-year time horizon, so towards 2030. Adopting the storylines of Berkhout et al. (2002), Cooper et al. (2008) and Langmead et al. (2009), we deployed the SRES approach of two orthogonal trends to our scenarios and focused on regionally plausible dimensions of societal change, i.e. low vs high population immigration and low vs high economic growth and prosperity in the Berau region (Table 2). At the same time, we developed our local scenario articulations to remain reasonably comparable to the four SRES scenarios (Busch 2006). For each driver, and some pressures, we critically explored a plausible trend for the Berau region given the narrative for each scenario (Table 2; cf. Zurek and Henrichs 2007). We presume that global climate change will involve an elevation in sea surface temperature and sea level, but that their extent will still be limited in 2030 (temperature increase between 1990 and 2030 $\sim$1°C for A2, sea level rise $\sim$8 cm; Bindoff et al. 2007; Christensen et al. 2007), compared to effects of human migration, population growth and economic development (Obidzinski and Barr 2003). Therefore, we have focused our analysis on these aspects of the scenarios as driving forces of change. We provide four scenarios in contrast to a business-as-usual trajectory (cf. Langmead et al. 2009).

Results and discussion

Our respondents were convinced that presently Berau's coastal waters witness a decline in fisheries yield due to overfishing, a decline in coral and seagrass cover due to increased riverine sediment delivery and sewage loading, and a decline in mangrove cover due to over-exploitation (Fig. 1). Consequent societal impacts appear to be an increased poverty among coastal communities that depend on fisheries and a reduced income from tourism. Also, our respondents foresee a reduced effectiveness of natural coastal defences due to parallel declines in reefs, seagrass beds and mangrove stands. The ultimate, primary driver is thought to be economic development of a sustained human immigration into the regency. Although sea level rise and sea surface temperature should not have risen substantially

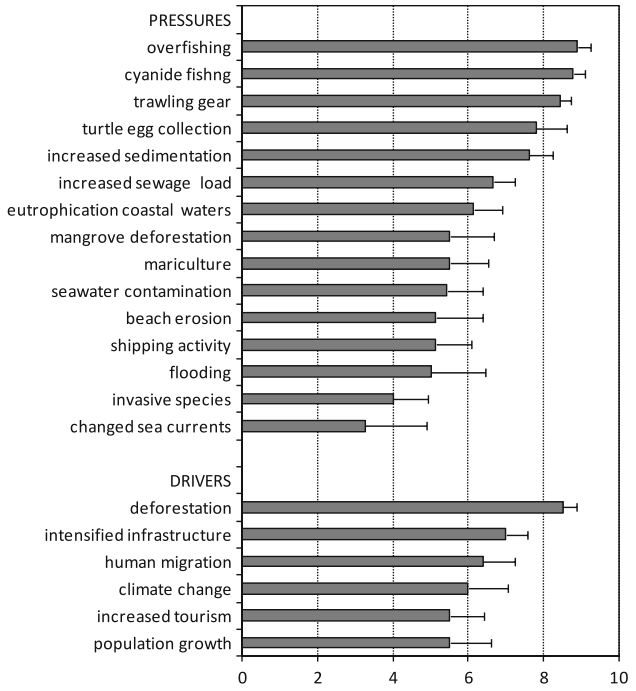

Fig. 2 Ranking by respondents of the importance of the long-listed drivers and pressures (cf. Table 1) leading to coastal ecosystem change in Berau. Presented is the mean importance (+1 standard error, using an importance scale of 1 and 10; see 'Approach'). Drivers and pressures have been sorted separately. Two respondent categories (stakeholder representatives and experts) differed in their priority setting for 1 driver (population growth) and 5 pressures (beach erosion, shipping activity, flooding, invasive species and sea currents). All were found more important by stakeholder representatives

yet by 2030 (Bindoff et al. 2007), our respondents were aware of its potential impacts. We have presumed, however, that the impacts of rising sea level and sea surface temperature on the selected ecosystem state indicators are yet low until 2030.

Our respondents ranked various aspects of fisheries as the most important pressure, with deforestation, a driver, as a close second (Fig. 2). Increased tourism and navigation were ranked lowest as drivers of adverse change, and enhanced flooding incidence and an increase in invasive species were ranked low as pressures. Variation in opinion among respondents increased for the lower ranks (Fig. 2, note the size of the standard errors). When we separate two respondent categories (stakeholder representatives and experts), these differ in their judgment of the priority of population growth as a driver and of the last five pressures in Fig. 2 (stakeholders found these more important than experts). This explains the increase in variation. With other words, unanimity was strongest for the highest ranking drivers or pressures. Impacts of fisheries and the decline in fish and turtle stocks are confirmed by Pet-Soede et al. (2000; though for Sulawesi, not Berau), Ismuranty et al. (2004) and Wiryawan et al. (2005). The catch of prized species is reported to drop (Wiryawan et al. 2005). Deforestation is well documented for East Kalimantan. Radday (2007) documented a decline that was particularly steep from 2000 till 2010, whereas the projected area of forest still present in the regency in 2020 amounts to 10% at most. It was still close to 100% in 1950. Also, the rapid increase in the human population due to the transmigration programme is well documented (Huttche 2002; Berau Ruma Kita 2008). Overall, we conclude that current trends in our major drivers, as deduced in the DPSIR articulation with our respondents, are well established in the literature from elsewhere in SE Asia. This correspondence serves as a support for our extrapolation in the scenarios.

Our respondents did not differ greatly in their views on the relative importance of trends in drivers, pressures and consequent state of coastal waters for the four scenarios. We have therefore compiled these into one diagram (Fig. 3). The current decline in state or condition of our indicators is thought to continue under the business-as-usual scenario. Notably, the two scenarios with continued immigration into the region (~A1 and A2) lead to enhanced pressures and a more strongly declining state of the coastal waters of Berau, though partly for different reasons (Fig. 3). Particularly, 'Peopling the world' (~A2) appears to be detrimental to coastal habitats and resources. The two scenarios with low immigration (~B1 and B2), in contrast, appear to have less adverse effects, in particular when governance at regency level is well established (Local Responsibility, ~B2). In the latter case, respondents foresee a drastic improvement in all state indicators; hence, waters become less turbid, due to reduced silt and sewage loads, corals, seagrass and mangroves recover, and so do the exploitable stocks of fish and shrimp. Turtle exploitation is probably minimized.

In conclusion, we observe that in applying the well-established DPSIR framework of causality, we have been able to convincingly link major drivers of societal change to consequent alterations of ecosystem state, though in a qualitative fashion. Second, we see that downscaling of SRES scenarios over a short-term time span of only 20 years does lead to major differences in the state of Beraus coastal ecosystems. Four contrasting scenarios also lead to major contrasts in the state of the coastal waters of Berau. At the extremes, our respondents foresee either turbid waters with minimal overexploited fish stocks and dwindled natural coastal defences of mangroves or clear waters with substantial fish stock, flourishing seagrass beds and corals and well-developed mangrove bands. Since the major discriminants among the four scenarios used here are migration, economic growth and strength of governance (Table 2), at least two are possibly influenced at the national policy level. Policy makers could have considerable influence here.

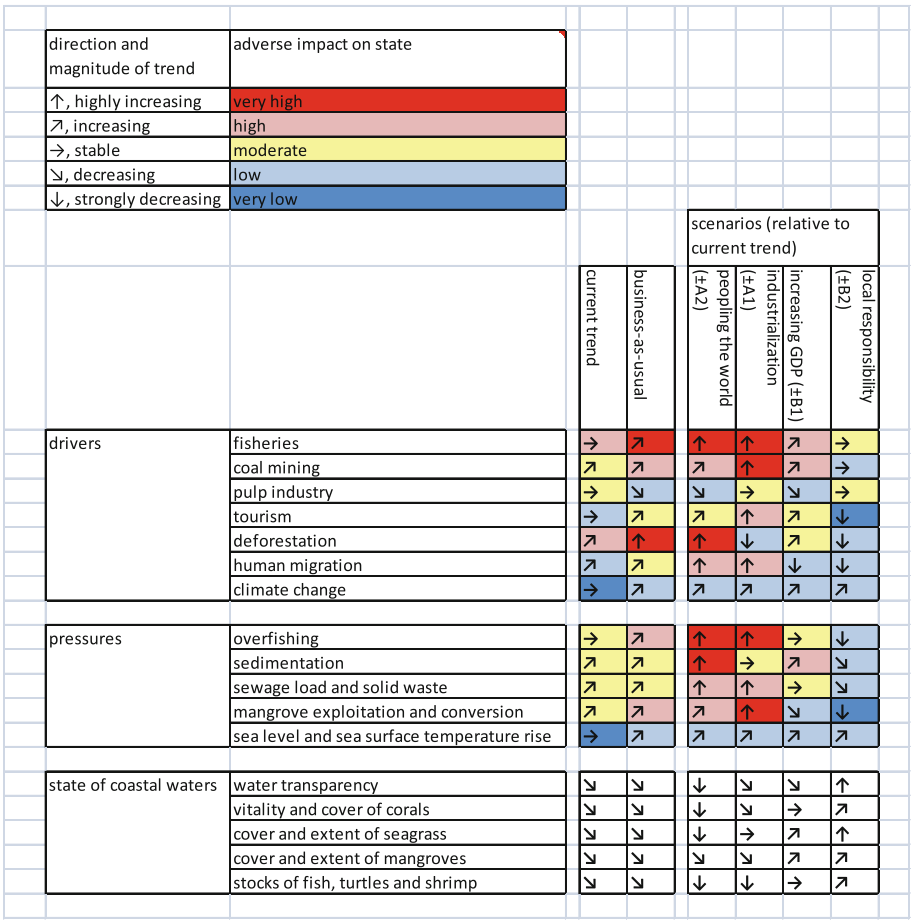

Fig. 3 Qualitative trend projections for the drivers, pressures and state of Berau's coastal zone for four local variants of the SRES scenarios, derived relative to the present trend and business-as-usual development

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Appendix

See Table 3.

Table 3 Consulted experts and stakeholder representatives

Function	Institution	Stakeholder matrix position
Director	Berau Lestari Foundation, East Kalimantan, Indonesia	Local, governance, stakeholder
Campaign manager	The Nature Conservancy—Berau Office, East Kalimantan, Indonesia	National, civic, stakeholder
Programme manager	The Indonesian Biodiversity Foundation, Jakarta, Indonesia	National, civic, stakeholder
Head, Dept Information Systems	Directorate General of Forest Protection and Nature Conservation, Jakarta, Indonesia	Local, governance, stakeholder
Member	Local community group focusing on East Kalimantan conservation, East Kalimantan, Indonesia	Local, civic, stakeholder
Agronomist	Bogor Agricultural University, Bogor, Indonesia	National, civic, expert
Social scientist	Wageningen Agricultural University, The Netherlands	International, civic, expert
Marine biologist	National Museum of Natural History Naturalis, Leiden, The Netherlands	International, civic, expert
Coral ecologist	Centre for Tropical Marine Research, Bremen University, Germany	International, civic, expert
Oceanographer	Center for Oceanography, Indonesian Institute of Sciences, Jakarta, Indonesia	National, civic, expert
Lecturer marine biology	Mulawarman University, East Kalimantan, Indonesia	National, civic, expert

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